Third Class of Compact Stars more Dense than Neutron Stars [1]

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There are two known classes of compact stars, white dwarfs, which were discovered in 1910 and neutron stars in 1967. Distinct classes (or families) of compact degenerate stars originate in properties of gravity; the distinction is made rigorous by the 'turning point' theorem of Wheeler and his collaborators [2]. The theorem assures that distinct families of stars, such as white dwarfs and neutron stars, are separated in central density by a region in which there are no stable configurations. Does General Relativity admit the possibility of a third distinct family of degenerate stars at higher density than neutron stars?

There is a good physical reason to doubt that a third family is allowed: The physical reason is the absence of an analogous mechanism to the one that ushers in the two known families. White dwarfs are stabilized by degenerate electron pressure which fails at such density that electron capture reduces their effectiveness. Stability is reestablished at densities about five orders of magnitude higher when the baryon Fermi pressure (and ultimately the short-range nuclear repulsive interaction) supports neutron stars. When neutron stars loose stability at their maximum mass, there is no evident mechanism for stabilizing a denser family. If quark deconfinement occurs, the Fermi pressure of baryons is replaced—not supplemented—by the pressure of their quark constituents. Indeed a phase transition will generally reduce the pressure at a given energy density.

Nevertheless, we show that the equations of stellar structure do admit stable solutions above neutron stars in density and we discuss the attributes required of the equation of state. The examples we have of a third family occur for the deconfinement phase transition given certain plausible combinations of parameters defining the nuclear and quark deconfined equations of state. Two of many examples of stellar sequences with a 'neutron star' branch and another stable higher density branch are shown in Fig. 1. The 'neutron star' sequence is terminated by the softening in the equation of state in the mixed phase when a substantial core of mixed phase is attained. A new sequence at higher density is stabilized by replacement of the mixed phase by a pure quark phase core. The stars near and at the termination of the "neutron star" branch and those of the third family are both hybrids in the sense that they have quark matter in the core, whether it be in mixed or pure phase, surrounded by confined nuclear matter. In this case there are stars of the same mass but radically different quark content and also of size.

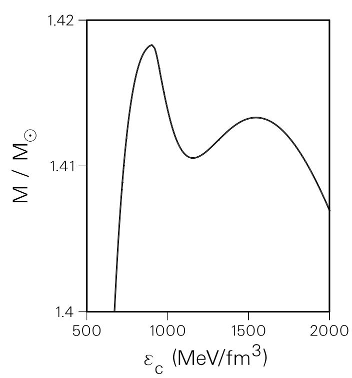

Figure 1: One of many examples of stellar sequences for which Neutron stars and a higher density stable family of 'non-identical twins' exist. Solid lines indicate the stable configurations.

References

[1] N. K. Glendenning and C. Kettner, Astron. Astrophys. **353** (2000) L9-12.

[2] B. K. Harrison, K. S. Thorne, M. Wakano and J. A. Wheeler, *Gravitation Theory and Gravitational Collapse*, (University of Chicago Press, 1965).